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Four historical steel bridges over the Mureș River

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Abstract

On the Mures River there are some representative historical steel bridges built at the end of the 19th and the beginning of the 20th century. They are located in important emplacements being an emblematical symbol for the local community. One of these structures – the bridge in Săvârșin - was successfully rehabilitated, being an example of a difficult strengthening work. In addition, the bridge in Arad, a monumental cantilever structure - a witness of the past, was renewed. The two other bridges, in Lipova and Săvârșin, are in a bad technical condition. All these structure are riveted. A duty of the present administration is to preserve these structures as historical and technical monuments. The paper describes the present situation of the structures.

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1. Introduction

On the Romanian national highway network, there are a small number of representative old steel bridges, erected at the end of the 19th and the beginning of the 20th century, which are witnesses of the past. Many of these are parabolic truss girders, typical for that period [1].

All these structures are riveted. The maintenance of these bridges is rather neglected and consequently the technical condition is poor. After two World Wars and many changes of the administration, the documentation is

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completely missing. The clearance of these structures does not correspond to the present request of the National Standard. Many members are damaged, due to the impact with vehicles. It is important to underline a certain inappropriate tendency of the administration to replace completely these structures.

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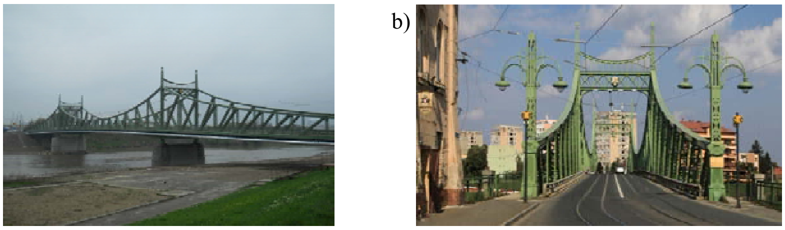


Fig. 1. Traian Bridge: (a) general view; (b) section view.

Many of these structures are situated in the western part of Romania, being manufactured at the Bridge Factory in Reschitz (Reşiţa) - St.E.G. (Kaiserliche und Königliche Privilegierte Österreichische Staatseisenbahn-Gesellschaft). Some of them will be presented in the following:

The historical representative cantilever truss girder bridge in the town of Arad (Fig.1), erected 1910-1913, is a reference work for that period and a symbol for the local community.

The bridge is a cantilever trough truss girder with three spans, L=50.05 + 85.30 + 50.05 = 185.40 m (Fig.2); the width of the carriageway is 8.05 m. The distance between the main truss girder axis is 9.6 m and the footpath on the lateral cantilever is 1.5 m. The structure was rehabilitated in 2011 and now is under normal traffic.

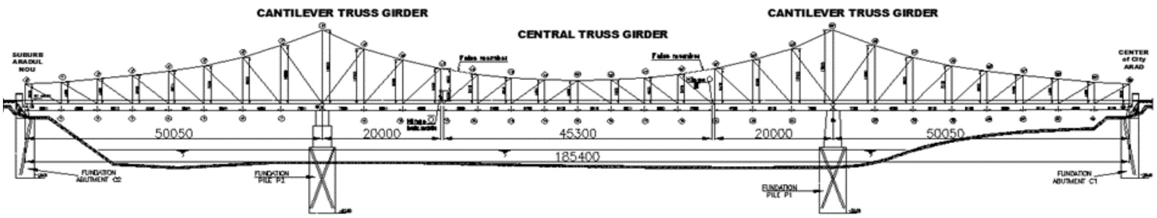


Fig. 2.The „Traian" Bridge – Schematic view.

The bridge in Săvârşin over the Mureş River on the local highway DJ 707 A is a remarkable structure with four spans, 4 x 39.8 m (Fig.3) that has been success fully rehabilitated in 2008. The European Prize for Rehabilitation of bridges was awarded in 2010 to the designers of the structure refurbishment (Fig. 4) [2].
The rehabilitation works included all the elements of the structure; direct and indirect strengthening was used.

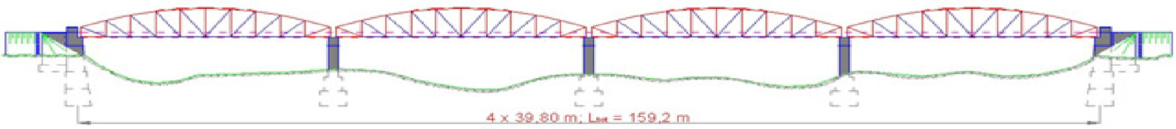
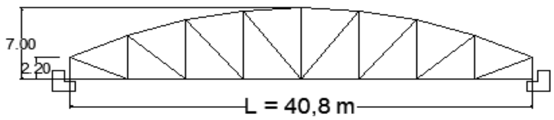


Fig. 3. Bridge in Săvârşin – schematic view.

Fig. 4.The Bridge in Săvârşin-2008 (after rehabilitation) – general view.

The bridge in the city of Câmpeni (Fig. 5a) carries out the connection between the two parts of the town (Fig. 5b).

a)



b)

Fig. 5. Bridge in Câmpeni: (a) schematic view; (b) general view.

This bridge is a simple supported parabolic symmetric truss girder. The structure consists wholly of riveted elements (L-Profiles, Flat Steel Plates). The bridge has one span of 40.80 m, 8 panels x 5.10 m. The width between the truss girder axes is 6.40 m. In present the bridge is in a satisfactory technical condition.

In the following two representatives not rehabilitated bridges, built in the same period are presented:
-the “Iron Bridge” in Lipova (in present used only as a pedestrian bridge);
-the bridge in Ilia used even now without any restriction.

2. Technical condition of the two bridges

The bridge from Lipova (Fig. 6a) - erected around 1896 – is situated in the middle of the city, being a direct connection to the Old Catholic Monastery “Sf. Maria” Radna (erected in 16th century by the Franciscan monks).

a)

b)

Fig. 6. (a) Pod Lipova – emplacement plan; (b) “the Iron Bridge” – Lipova – general view.

The bridge served for many years as main connection on the National Road from Deva (DN 58) to Timişoara (Fig. 6b).

This structure has three spans, L=48 m each and a total length of 144 m (Fig. 7). The width of the carriageway is 6.0 m and the distance between the main girders axis is 6.4 m. The height of the middle post is h=6.95 m (h/L≈1/7). The existent floor is constituted of stringers and cross girders, which are simple supported elements. The old classical layers consisting of Zorres elements filled with ballast were replaced in the ’60 by a reinforced concrete deck (without composite action) with a thickness of approximately 0.50 m.

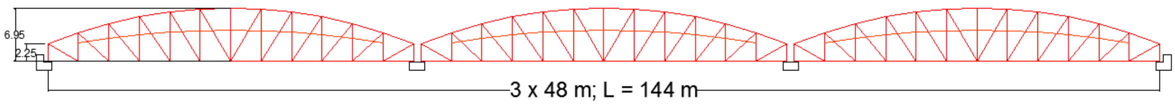


Fig. 7. The Bridge in Lipova – schematic view.

The particularity of this structure consists in the third intermediate chord, which gives a remarkable aspect and reduces the buckling length of the compressed posts.

Due to the complete lack of maintenance, the bridge has many defects:

- Corrosion (Fig. 8a);
- Sectioned and deformed posts (Fig. 8b);
- Damaged elements due to the impact with vehicles (Fig. 8c);
- Jammed bearings (Fig. 8d);
- Old pipeline out of service with an unaesthetic aspect (Fig. 8e).

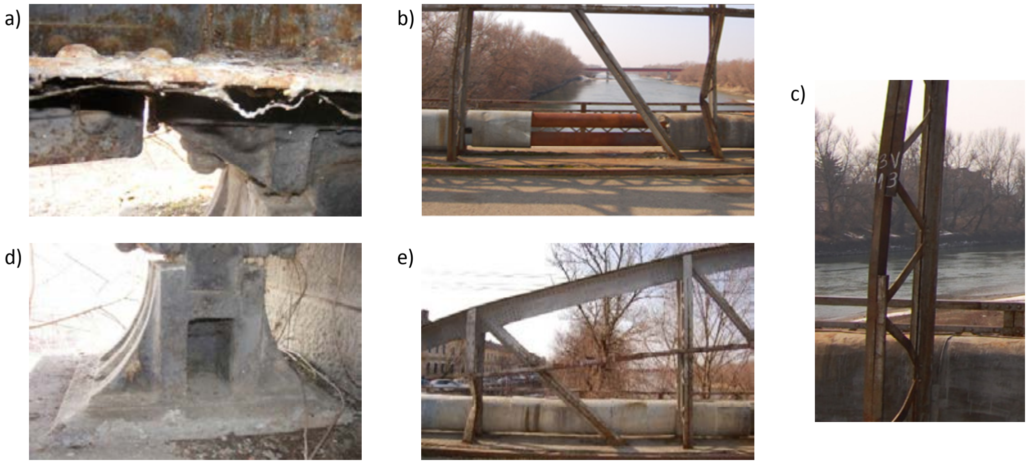


Fig. 8. Defects of the Bridge in Lipova: (a) corrosion; (b) damaged post; (c) sectioned and deformed post; (d) jammed bearings; (e) old pipeline out of service with unaesthetic aspects.

In 1996 a new bridge was erected in the neighborhood of the old bridge. Consequently, the structure was transformed in a pedestrian bridge. The proposal is to transform the bridge in an emblematical place in the old center of the town. In this direction the following operation are proposed:

-completely removing of the pavement;

-sand blasting;

-necessary repairs – on the base of a project;

-new function: touristic info point, happenings spot. The bridge connects two main objectives (the old fortress -in rehabilitation- and the Franciscan Monastery - also in rehabilitation), with the old city center;

-painting of the structure;

The city of Lipova has no documentation regarding the structure.

The second analyzed structure is a bridge in ilia.

In the past the bridge in Ilia carried out the connection between the National Roads DN 68A and DN7. For a long period, it was the only option for crossing the Mureș River on the National Road Arad – Deva (Fig. 9a).

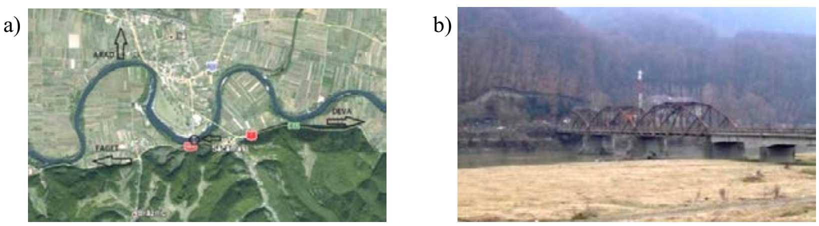


Fig. 9. The Bridge in Ilia: (a) emplacement plan; (b) general view.

The bridge astonishes through its slenderness and elegance, having a marvelous integration in the surroundings (Fig. 9b).

The structure has three spans, of L=41.5 m resulting a total length of 124.5 m (Fig. 10). Each span consists of 10 unequal panels. The marginal panels have a length of 4.15 m and the rest of them a length of 8.3 m. The constitution is similar to the previous bridge, the main girders being parabolic truss girders. The width of the carriageway is 6.0 m and the width of the bridge between the main girder axes is 6.4 m. The height of the middle post is h = 7.4 m (h/L≈1/6). The existent floor beams, stringers and cross girders, are simple supported elements. The deck consists of Zorres elements filled with ballast, supporting an asphalt surface.

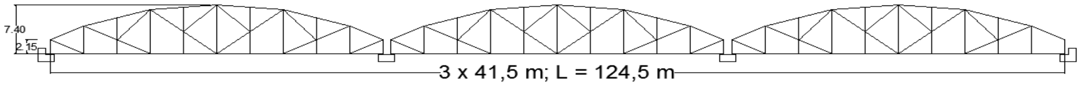


Fig. 10. The bridge in Ilia – schematic view.

The particularity of this bridge consists in the complementary subdivision system conceived to reduce the buckling length of the compressed upper chord (Fig. 11).

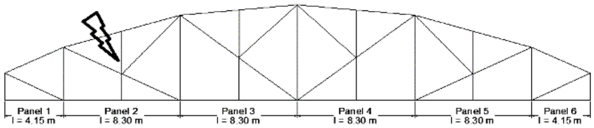


Fig. 11. System for reducing the buckling length of the upper chord.

More or less, this bridge features the same defects as the “Iron Bridge” in Lipova. As it is mentioned above, the bridge is being used without any limitations. Therefore there are some side effects such as the strong vibrations amplified also by the growth of the dynamic effect due to the damaged deck (Fig. 12a).

a)  b) 

Fig. 6. (a) Bridge in Ilia (July 2008); (b) heavy lorry on the bridge in Ilia (April 2012).

During some repair works of the new parallel concrete bridge, the “light” traffic was diverted on the old steel bridge (Fig. 12b). Generally, the behaviour of the foundations is satisfactory. Only some reparations are necessary together with the regulation of the river bed (Fig. 13a).

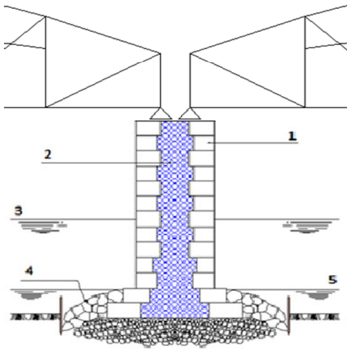
a)  b) 

Fig. 13. (a) piers of the bridge in Lipova; (b) the foundation of the bridge: 1 – natural stone, 2 – cyclopean.

Similar to other already investigated structures, the foundation is a direct one (Fig. 13b). It was executed in dry conditions at a low water level.

Material tests have not been yet performed. According to our experience, the steel is a mild one.

3. Stress calculation

The rehabilitation of the bridges is a complex matter. The Romanian Highway Administration adopted a qualitative verification methodology based on the appreciation by the experts of the technical condition of the structure [3].

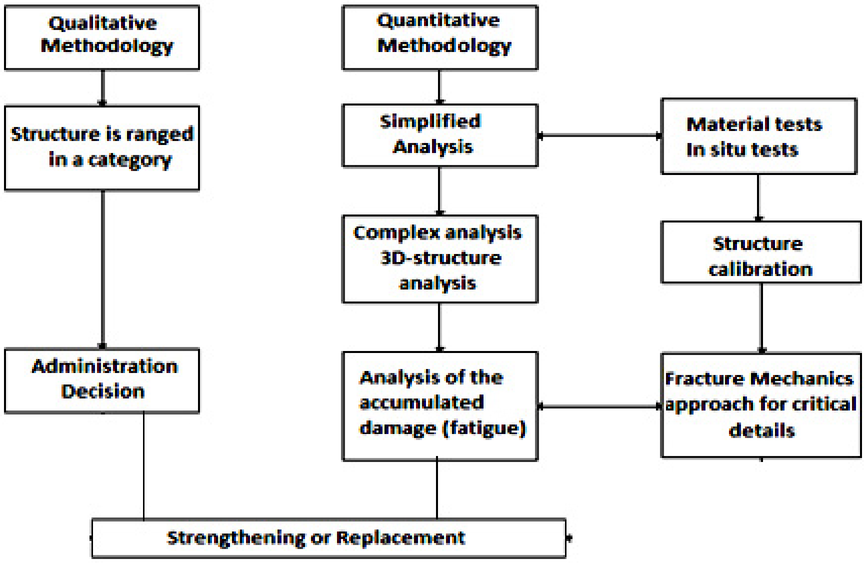


Fig. 14. Methodology for the verification of old existing highway bridges [7]

A complete verification includes:

-in a first step, the calculus with traditional methods;

-if the usual conditions are not fulfilled, a more refined methodology must be adopted;

-modeling the bridge as a space structure; the calculus can be performed using a specialized computer program;

-determination of the remaining fatigue life;

-proposals for strengthening (or in extreme situations replacement);

In situ tests are useful, but are very expensive; they are recommended only for complex structures (continuous girders, skew bridges etc.)

The recommendation of the old Romanian Standards is to calculate with an allowable stress of 150 N/mm^2 [4].

The bridge in Lipova was calculated for a uniformly distributed load of 5kN/m2 used to represent crowd loading, according to the Eurocode 1 [5]. The same old Romanian Highway Standard considers this loading case to be in the 3rd group of load combinations, that means an allowable stress of 190 N/mm^2 .

For bridges in alignment a space analysis gives similar results to a plane analysis. The structure was calculated in a first step, as a classical plane truss girder using influence lines. The results are represented under the form of β coefficient (Fig. 15, 16):

$$\beta \le \frac{\sigma_a - \sigma_g}{\psi \sigma_c} \ge 1.0 \tag{1}$$

where:

σ_a - allowable stress (150 N/mm^2- Ilia, 190 N/mm^2- Lipova);

σ_g - stress induced by the dead load;

σ_c - stress induced by the convoy;

ψ – dynamic factor.

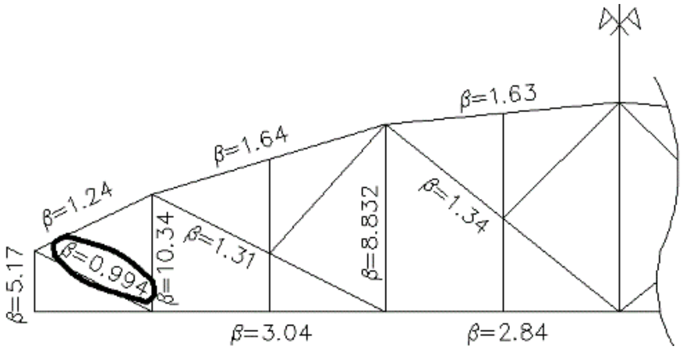


Fig. 15. Values of β (Ilia)

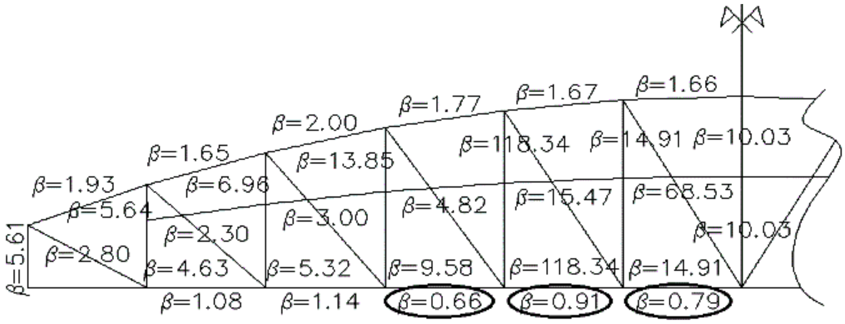


Fig. 167. Values of β (Lipova)

It can be seen, that for the bridge in Lipova, the stresses in some elements are higher than the allowable ones. The cause is the concrete deck with h=50 cm provided in the early ’60 during the strengthening of the structure.

For the assessment of the remaining service life it was practically impossible to perform an analysis based on the classical method of the damage accumulation hypothesis Palmgren – Langer – Miner. This can be explained by the fact that it is very difficult to recognize the stress history of the structure. Approximations made in the establishing of the past traffic lead to irrelevant results. Fatigue life calculations based on the classical method sometimes lead to the conclusion that there is no remaining service life, although there are no cracks observed in the structural elements.

Using a diagram given in the Swiss regulation [6], we can appreciate the damage accumulation from the past for the bridge in Ilia (for the bridge in Lipova an assessment of the remaining fatigue life is not necessary, as it will be used only as a pedestrian bridge). If we consider that the bridge in Ilia is situated on a former national highway the traffic coefficient “α” will be determined using [6].

According to the Swiss standard with the relation:

$$\Delta\sigma_e \leq \frac{\Delta\sigma_c}{\gamma_{fat}} \tag{2}$$

where:

$\Delta\sigma_e = \alpha\,\Delta\sigma(\mathrm{Q})_{fat}$

$\gamma_{fat} = 1.10$

α = traffic coefficient

$\Delta\sigma = \Delta\sigma_{\max} - \Delta\sigma_{\min}$, stress range

For riveted structures, the value of σ_{at}= 80 N/mm^2 (admitted stress range in case of riveted elements) can be found in the same regulations.

For exemplification, the verification of the most tensioned and the most compressed element will be presented.

Table 1. The verification of the most tensioned.

The main girder, upper chord (marginal panel) – compressed element	The final diagonal (tensioned element)
$\Delta\sigma = 39.23\,\mathrm{N/mm^2}$	$\Delta\sigma = 65.6\,\mathrm{N/mm^2}$
$\alpha = 0.6$ (national highway)	$\alpha = 0.59$ (national highway)
$\Delta\sigma_c = 0.6 \times 39.23 = 23.59\,\mathrm{N/mm^2}$	$\Delta\sigma_c = 0.59 \times 65.6 = 38.35\,\mathrm{N/mm^2}$
$< \quad 80/1.1 = 72.7\,\mathrm{N/mm^2}$	$< \quad 80/1.1 = 72.7\,\mathrm{N/mm^2}$

By taking into consideration all investigated cases it has been concluded that accumulated damage in the case of this structure is satisfactory, in conclusion the bridge can be strengthen.

4. Conclusions

The paper gives an overview of the assessment methodology for old steel highway bridges.

Every case must be separately considered.

Nevertheless the rehabilitation of such representative structure is one of the main tasks of the bridge engineers.

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